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(54) **PLUNGER PACKING WITH WEDGE SEAL HAVING EXTRUSION RECESS**

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F16J 15/18	(2006.01)
F16J 15/56	(2006.01)

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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,037,460	A	6/1962	Guest	
3,666,382	A	5/1972	Rasmussen	
3,765,690	A	10/1973	Sievenpiper	
3,786,551	A	1/1974	Gregg et al.	
3,907,307	A *	9/1975	Maurer et al.	277/513

(Continued)

FOREIGN PATENT DOCUMENTS

CN	201425021	Y	3/2010
CN	201621057	U	11/2010

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 61/593,710, filed Feb. 1, 2012; First Inventor: Scott Skurdalsvold.

(Continued)

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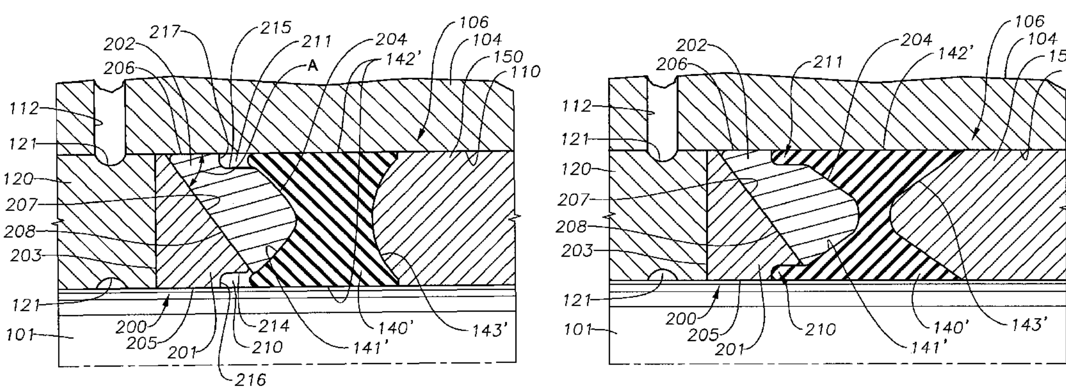
(57) **ABSTRACT**

A seal assembly is disposed in an annular recess in a cylinder chamber between a pump cavity and a pump exterior. The seal assembly includes a main seal and a back-up seal and seals to a pump plunger disposed within the cylinder chamber. The back-up seal includes an extrusion recess extending from a surface of the back-up seal adjacent the main seal along an inner or an outer diameter of the back-up seal. During pumping operations the plunger strokes through the cylinder chamber causing the main seal to extrude into the extrusion recess to form a seal between the plunger and the cylinder chamber.

32 Claims, 3 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,009,515	A	3/1977	Racin	
4,138,144	A	2/1979	Pierce, Jr.	
4,380,342	A	4/1983	Fling et al.	
4,589,180	A	5/1986	Vachon	
5,003,681	A	4/1991	Schley	
5,018,261	A	5/1991	Markous	
5,577,737	A	11/1996	Lacy	
6,195,863	B1	3/2001	Blake	
6,415,487	B1	7/2002	Leimer	
6,574,846	B1	6/2003	Kang	
6,712,362	B2	3/2004	Krappmann et al.	
6,755,099	B2	6/2004	Huang	
6,758,478	B1	7/2004	Moreno	
6,869,079	B2	3/2005	Zheng	
7,194,948	B2	3/2007	Liu	
7,389,579	B2	6/2008	Rode	
7,748,095	B1	7/2010	Phane	
8,402,880	B2	3/2013	Patel et al.	
8,418,363	B2	4/2013	Patel	
2003/0030228	A1	2/2003	Graziani et al.	
2004/0046330	A1	3/2004	Wobben	
2004/0170507	A1	9/2004	Vicars	
2004/0255445	A1	12/2004	Ploeger et al.	
2005/0201881	A1	9/2005	Jensen et al.	
2008/0136118	A1 *	6/2008	Ando et al.	277/530
2009/0011225	A1	1/2009	Moronuki et al.	
2010/0143163	A1	6/2010	Patel et al.	
2010/0160710	A1	6/2010	Strickland	
2010/0325888	A1	12/2010	Hawes	
2013/0232789	A1	9/2013	Patel	

FOREIGN PATENT DOCUMENTS

CN	201730815	U	2/2011
CN	103370543	A	10/2013
JP	7113426	B	12/1995
JP	2002161982	A	6/2002
JP	2003065439	A	3/2003
JP	2008539364	A	11/2008
KR	1019990079544		11/1999
KR	100383826	B1	5/2003
KR	100402825	B1	10/2003
KR	798807	B1	1/2008
WO	WO-9950578	A1	10/1999
WO	WO-2008137515	A1	11/2008
WO	WO-2011002902	A2	1/2011
WO	WO-2011008763	A2	1/2011
WO	WO-2012083179	A2	6/2012

OTHER PUBLICATIONS

International Search Report and Written Opinion (PCT/US2011/065514), dated Aug. 24, 2012.

International Search Report and Written Opinion for Application No. PCT/US2010/040628 mailed on Jan. 27, 2011, 7 pages.

International Search Report and Written Opinion for Application No. PCT/US2010/041832 mailed on Feb. 1, 2011, 8 pages.

Notice of Allowance mailed Dec. 17, 2012, by the USPTO, re U.S. Appl. No. 12/835,496.

Office Action mailed Feb. 12, 2013, by the USPTO re U.S. Appl. No. 12/826,493.

Office Action mailed Sep. 13, 2013, by the USPTO, re U.S. Appl. No. 13/863,070.

Restriction Requirement mailed Nov. 5, 2012, by the USPTO, re U.S. Appl. No. 12/826,493.

Restriction Requirement mailed Oct. 23, 2012, by the USPTO, re U.S. Appl. No. 12/835,496.

* cited by examiner

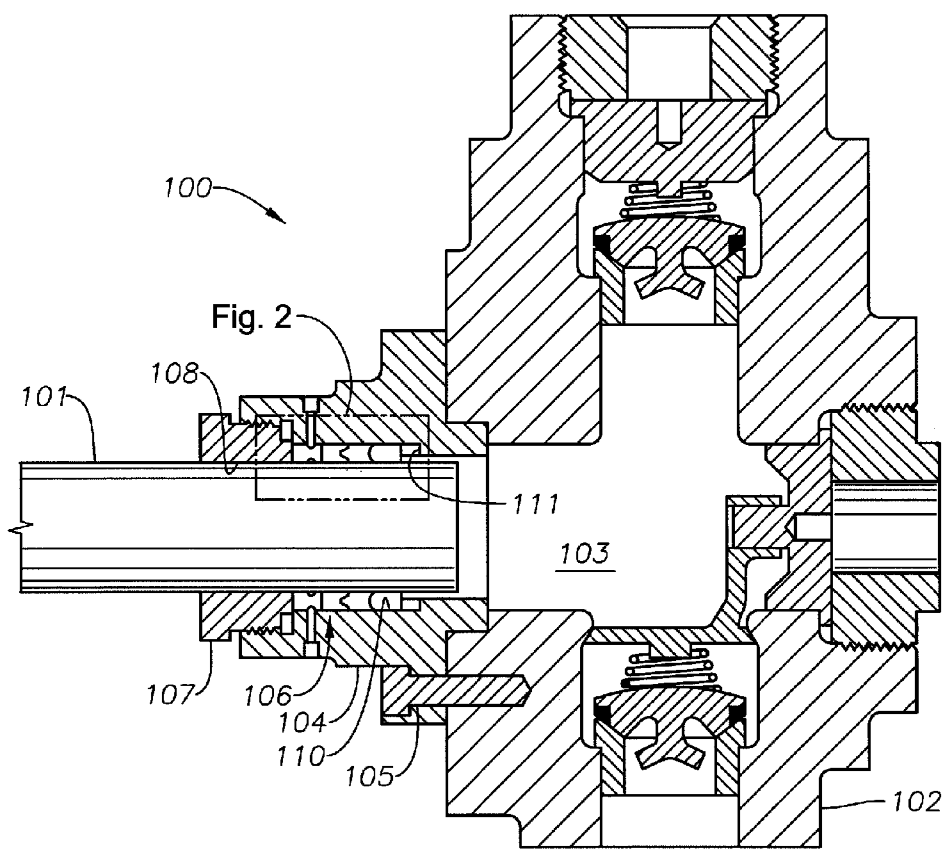


Fig. 1

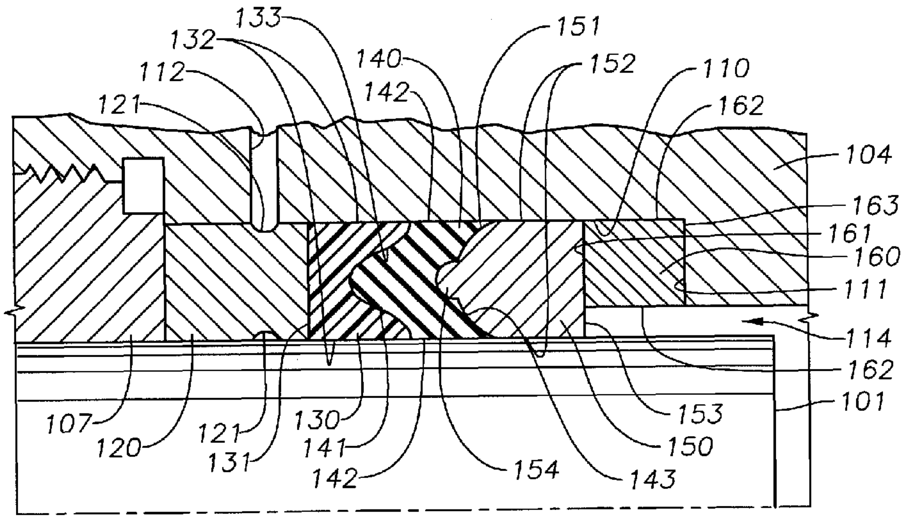


Fig. 2
(Prior Art)

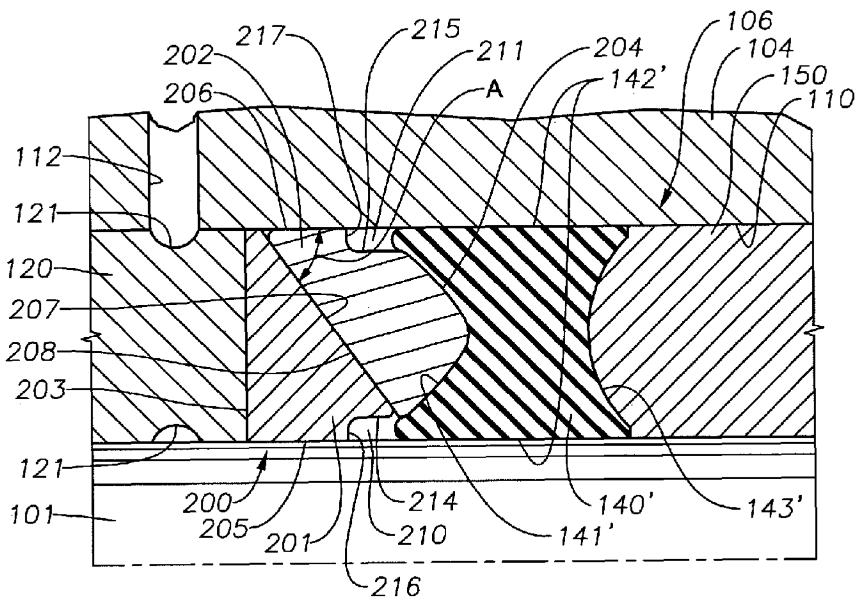


Fig. 3

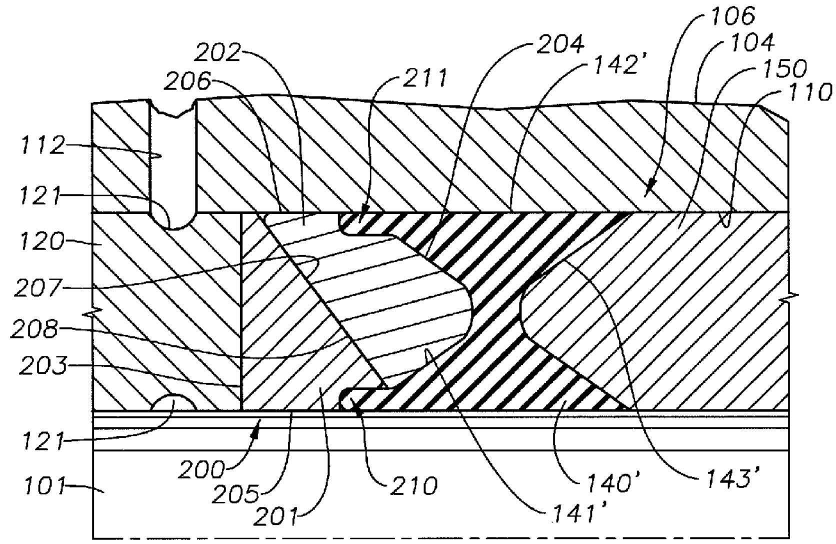

106
104
150
110
204
142'
211
202
206
112
121
120
207
208
203
121
200
205
201
210
141'
140'
143'
101

Fig. 4

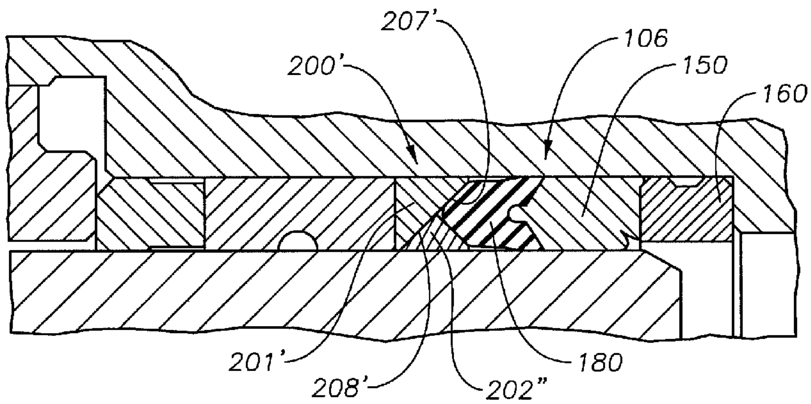

207'
106
150
160
200'
201'
208'
202"
180

Fig. 5

PLUNGER PACKING WITH WEDGE SEAL HAVING EXTRUSION RECESS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 61/423,686, filed on Dec. 16, 2010, and herein incorporated by reference in its entirety.

TECHNICAL FIELD

The disclosed embodiments relate in general to reciprocating pumps and, in particular, to a packing assembly seal between a pump housing and a pump plunger.

BACKGROUND OF THE DISCLOSURE

In oil field operations, reciprocating pumps are often used for various purposes. Reciprocating pumps utilize a plunger that reciprocates in and out of a pump housing to move fluid through a cavity defined by the pump housing. A motor rotates a crankshaft connected to the plunger to pull fluid into the pump cavity through a fluid intake and push fluid out of the pump cavity through a pump outlet. The plunger extends through a cylinder chamber of the pump housing to interact with the cavity. A seal in the cylinder chamber of the pump housing prevents leakage of fluid from around the plunger during pumping operations. Generally, a seal or packing assembly is composed of different types of seals to increase the sealing impact of the seal assembly. The seal assembly is disposed within a recess of the cylinder chamber.

In one type of seal assembly, a main seal or pressure ring is sandwiched between at least two other seal types. Generally the main seal will be formed of a pliable or rubber-like material. During operation, the seal assembly is compressed, causing the main seal to flair into contact with the pump housing at the cylinder chamber and the plunger. The rubber material of the main seal flows like a thick liquid during operation, which results in the pressure in the main seal to drop due to flow loss and wall friction loss. The lower pressure allows the higher pressure of the pumped fluid to flow around both sides of the main seal, causing it to hydraulically float and preventing seal formation. Instead, the seal assembly seals at narrow gaps formed between a ring adjacent the main seal and both the housing and the plunger. The pliant material of the main seal will flow into this gap, increasing the contact pressure between the elastomer and the walls of the recess. The contact pressure is higher than the pumping pressure, which causes the main seal to form a seal in the narrow gaps. The narrow gaps run the length of the adjacent ring. The narrow width of the gaps and the length of the extrusion into the gaps may exceed the pliant properties of the main seal, causing extreme fatigue and failure of the main seal, and ultimately failure of the pump. Thus, a seal assembly is needed that provides a seal between the plunger and the pump housing at the cylinder chamber while relieving stress and fatigue on the main seal to extend the life of the main seal and ultimately of the packing assembly.

SUMMARY

In a first aspect, embodiments are disclosed of a seal assembly disposed within an annular recess of a cylindrical chamber for receiving a plunger. The seal assembly includes a main seal having an axis, a forward side, and a rearward side, and a back-up seal in abutment with the rearward side of

the main seal, the back-up seal having inner and outer diameter cylindrical surfaces. The back-up seal made of a material harder than a material of the main seal and is expansible in radial width between the inner and outer diameter cylindrical surfaces in response to an axially directed rearward force. The at least one extrusion recess on a forward side of the back-up seal receives an extruded portion of the rearward side of the main seal during a forward stroke of the pump plunger.

In certain embodiments, the back-up seal includes a rearward wedge ring and a forward wedge ring each of the wedge rings having a cylindrical surface. The rearward wedge ring and the forward wedge ring each have a mating angled surfaces configured to slide against one another to increase their combined radial width relative to an axis of the cylinder chamber during operation of the pump.

In certain embodiments, the rearward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

In certain embodiments, the forward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

In other embodiments, the rearward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

In certain embodiments, the forward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

In certain embodiments, the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

In certain embodiments, the extrusion recess extends a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings, defining a forward facing step at a rearward end of the extrusion recess.

In certain embodiment, the extrusion recess has an entrance substantially at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

In certain embodiments, the forward wedge ring has a forward facing convex surface adjacent to and in contact with a rearward facing concave surface of the main seal, and the extrusion recess is positioned at a rearward end of the convex surface portion.

In certain embodiments, the at least one extrusion recess comprises two extrusion recesses, each located at a forward edge of one of the cylindrical surfaces.

In certain embodiments, the extrusion recess has an entrance substantially at an intersection of the inclined surface with the cylindrical surface of at least one of the wedge rings.

In a second aspect, embodiments are disclosed of a reciprocating pump assembly. The pump assembly includes a pump housing defining a pump cavity in an interior of the housing and a cylinder chamber extending from an exterior of the pump housing to the pump cavity. A plunger is disposed at least partially within the cylinder chamber and configured to reciprocate into and out of the pump cavity in rearward and forward directions between suction and discharge strokes, respectively. An annular recess is formed in the cylinder chamber and positioned between an exterior of the pump housing and the pump cavity. A seal assembly having a main seal in abutment with a wedge-type seal is disposed within the recess; the seal assembly is configured to seal the plunger to the cylinder chamber. The wedge-type seal comprises a rearward wedge ring and a forward wedge ring each of the wedge rings having a cylindrical surface. The rearward wedge ring and the forward wedge ring have mating angled surfaces configured to slide against one another to increase their combined radial width relative to an axis of the cylinder chamber during a discharge stroke. At least one extrusion recess is formed on a forward edge of the cylindrical surface on at least one of the wedge rings. During the discharge stroke of the plunger a rearward portion of the main seal extrudes into the extrusion recess.

In certain embodiments, the at least one extrusion recess is on a forward edge of the cylindrical surface.

In certain embodiments, the rearward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

In certain embodiments, the forward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

In certain embodiments, the rearward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

In certain embodiments, the forward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

In other embodiments, the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

In certain embodiments, the extrusion recess extends a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings, defining a forward facing step at a rearward end of the extrusion recess.

In certain embodiments, during the discharge stroke, one of the cylindrical surfaces is in contact with the plunger and the other is in contact with the annular recess in the cylindrical chamber.

In certain embodiments, the extrusion recess has an entrance substantially at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

In certain embodiments, an inner one of the cylindrical surfaces is in sliding engagement with the plunger, and the extrusion recess is located on the cylindrical surface of the inner one of the cylindrical surfaces.

In certain embodiments, the at least one extrusion recess comprises two extrusion recesses, each located at a forward edge of one of the cylindrical surfaces.

In certain embodiments, the forward wedge ring has a forward facing convex surface adjacent to and in contact with a rearward facing concave surface of the main seal, and the extrusion recess is positioned at a rearward end of the convex surface portion.

In certain embodiments, the extrusion recess has an entrance substantially at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

In certain embodiments, the main seal is formed of a material that is softer than the material of the wedge ring.

In a third aspect, embodiments are disclosed of a method for sealing a plunger to a pump housing within a reciprocating pump assembly. The method provides a seal assembly having a main seal and a back-up seal, the back-up seal being of a material harder than a material of the main seal and being expansible in radial width between inner and outer diameter cylindrical surfaces in response to an axially directed rearward force, and at least one extrusion recess for receiving an extruded portion of the rearward side of the main seal during a forward stroke of the pump plunger. The method positions the seal assembly within a recess of a cylinder chamber that extends between an exterior of the pump housing and a pump cavity. The method inserts a plunger into the cylinder chamber so that an exterior diameter of the plunger contacts the seal assembly. The method reciprocates the plunger into and out of the pump cavity through the cylinder chamber. As the plunger moves forward relative to the seal assembly, the method expands a radial width of the back-up seal and extrudes a portion of the main seal into the extrusion recess of the back-up seal.

In certain embodiments, the method further comprises the extrusion recess is on a forward side of the back-up seal at an intersection of the forward side with one of the cylindrical surfaces and extending the extrusion recess a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings to define a forward facing step at a rearward end of the extrusion recess.

In certain embodiments, the method comprises contacting the plunger with one of the cylindrical surfaces of the back-up seal and contacting the annular recess in the cylindrical chamber with the other cylindrical surface of the back-up seal.

In certain embodiments, an inner one of the cylindrical surfaces is in sliding engagement with the plunger, and the method further comprises locating the extrusion recess on the cylindrical surface of the inner one of the cylindrical surfaces.

In certain embodiments, the at least one extrusion recess comprises two extrusion recesses and the method comprises locating each extrusion recess at a forward edge of one of the cylindrical surfaces.

In certain embodiments, the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

Other aspects, features, and advantages will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, which are a part of this disclosure and which illustrate, by way of example, principles of any embodiments disclosed.

DESCRIPTION OF THE FIGURES

The accompanying drawings facilitate an understanding of the various embodiments.

FIG. **1** is a sectional view of a portion of a reciprocating pump showing a plunger and fluid end.

FIG. **2** is a detail view of a prior art packing assembly in the fluid end of FIG. **1**, taken as indicated in FIG. **1**.

FIG. **3** is a detail view of an embodiment of the packing assembly.

FIG. **4** is a detail view of the packing assembly of FIG. **3** during operation.

FIG. **5** is a detail view of another embodiment of the packing assembly.

DETAILED DESCRIPTION

Referring to FIG. **1**, there is shown a sectional view of a portion of a reciprocating pump **100** used in oilfield fracturing operations. The reciprocating pump **100** comprises a plunger **101** and a housing or fluid end **102**. The plunger **101** couples to a crankshaft (not shown) in the power end of the reciprocating pump. In the illustrated embodiment, the crankshaft strokes the plunger **101** horizontally into and out of the housing **102** alternately drawing fluid into a cavity **103** defined by the housing **102** and forcing fluid out of the cavity **103**. The horizontal strokes of the plunger **101** may be characterized as a rearward or intake stroke when the plunger **101** moves away from or out of the cavity **103** and a forward or discharge stroke when the plunger **101** moves toward or into the cavity **103**. As used herein, rearward will generally refer to movement away from the cavity **103**. Similarly, forward will generally refer to movement toward the cavity **103** or the surfaces facing the cavity **103**. In an operational use of the pump **100**, the fluid is forced into a geologic formation to fracture the formation to enhance hydrocarbon production. In another operational use of the pump **100**, the fluid may be circulated through a drill string during drilling operations. A person skilled in the art will understand that the embodiments disclosed herein may be applied to any type of reciprocating pump.

A packing gland or housing flange **104** couples and aligns the plunger **101** to the housing **102** with at least one bolt **105**. A person skilled in the art will understand that the housing flange **104** may couple to the housing **102** by more than one bolt **105** or through alternate means. In the illustrated embodiment, the housing flange **104** defines a cylinder **108** of a size and shape such that the plunger **101** may alternately stroke into and stroke out of the cylinder **108** into the cavity **103** with minimal clearance between an interior wall defining the cylinder **108** and the plunger **101**. The housing flange **104** further defines an annular recess **110** extending inward from the interior wall of the housing flange **104** defining the cylinder **108**. An outward facing shoulder **111** comprises an annular vertical portion of the recess **110** opposite a threaded retainer nut **107** described in more detail below. An exterior surface of the plunger **101** is proximate to the recess **110**. The packing assembly **106** substantially fills the recess **110** between the housing flange **104** and the plunger **101**. The threaded retainer nut **107** couples to the housing flange **104** with coacting threads defined by the housing flange **104**. In this manner, the threaded retainer nut **107** applies a force against the packing assembly **106** pressing the packing assembly **106** against the shoulder **111** and causing the packing assembly **106** to seal the cylinder **108** between the plunger **101** and the housing flange **104**.

Referring now to the prior art illustration of FIG. **2**, there is shown a portion of the reciprocating pump **100** of FIG. **1** illustrating additional details of the packing assembly **106**. As illustrated in FIG. **2**, the packing assembly **106** comprises a brass lantern ring **120**, a back-up seal or hard plastic ring **130**, a main seal **140**, a header seal **150**, and a junk ring **160**. In the illustrated embodiment, the brass lantern ring **120** comprises a ring having a substantially rectangular cross section. The brass lantern ring **120** substantially fills a portion of the recess **110** abutting the threaded retainer nut **107**. The brass lantern ring **120** defines an annular groove **121** proximate to a lubricant passage **112** defined by the housing flange **104**. The groove **121** and the lubricant passage **112** are configured, to pass a lubricant through the housing flange **104** for distribution in the cylinder **108** between the housing flange **104** and the plunger **101**.

The hard plastic ring **130** abuts an end of the brass lantern ring **120** opposite the threaded retainer nut **107**, substantially filling a portion of recess **110**. A cross section of the hard plastic ring **130** is defined by a rearward or an annular flat vertical surface **131**, inner and outer diameter cylindrical surfaces **132**, and a forward or an annular concave surface **133** opposite the flat vertical surface **131**. In the illustrated embodiment, the flat vertical surface **131** abuts the vertical end of the brass lantern ring **120** opposite the threaded retainer nut **107**. Preferably, the hard plastic ring **130** comprises a material such as a polyether ether ketone (PEEK), although other materials may be used.

In the illustrated embodiment, the main seal **140** abuts the concave surface **133** of the hard plastic seal **130** opposite the brass lantern ring **120**, substantially filling a portion of the recess **110**. A cross section of the main seal **140** is defined by a rearward annular convex surface **141** abutting and conforming to the annular concave surface **133** of the hard plastic ring **130**. The cross section is further defined by inner and outer diameter cylindrical surfaces **142**, and a forward annular concave surface **143** opposite the convex surface **141**. The main seal **140** comprises a soft rubber material such as hydrogenated nitrile butadiene rubber (HNBR) or the like, although other materials may be used.

The header seal **150** abuts the concave surface **143** of the main seal **140** opposite the hard plastic seal **130**, substantially filling a portion of the recess **110**. A cross section of the header seal **150** is defined by an annular convex surface **151** abutting and conforming to the annular concave surface **143** of the main seal **140**. The cross section is further defined by inner and outer diameter surfaces **152**, and an annular vertical surface **153** opposite annular convex surface **151**. The vertical surface **153** defines an annular protrusion **154** opposite the annular convex surface **151** extending toward the junk ring **160**. In a natural state, the inner diameter surface **152** bulges radially inward. The plunger **101** deforms the inner diameter surface **152**, causing it to exert an axial energizing force on the main seal **140**. Preferably, the header seal **150** comprises a material softer than the main seal **140**.

The junk ring **160** comprises a ring abutting the vertical surface **153** of the header seal **150** and the shoulder **111** defined by the housing flange **104**. The junk ring **160** substantially fills a remaining portion of the recess **110**, thereby securing the packing assembly **106** within the housing flange **104**. A cross section of the junk ring **160** is defined by an annular surface **161** abutting the vertical surface **153** of the header seal **150**. When the packing assembly **106** is energized, described in more detail below, the surface **161** deforms the protrusion **154** of the header seal **150**. The cross section of the junk ring **160** is further defined by inner and outer diameter surfaces **162**, and an annular vertical surface **163** opposite the surface **161**. The inner diameter **162** of the junk ring **160** is greater than the outer diameter of the plunger **101**, thereby defining an annular gap **114**.

In operation, the threaded retainer ring **107** is tightened, exerting an axial force against the brass lantern ring **120**. The force exerted by the threaded retainer ring **107** causes a reacting force in the shoulder **111**. These opposing forces transfer through the packing assembly **106** and cause the header seal **150** and the protrusion **154** to deform. The deformation of the header seal **150** and the protrusion **154** exerts a setting force on the main seal **140** pressing the inner and outer diameter surfaces **142** into contact with the interior wall of the housing flange **104** and the surface of the plunger **101**. The HNBR material of the main seal **140** flows like a thick liquid causing the internal pressure of the main seal **140** to drop due to flow loss and friction loss along the length of the main seal **140** moving away from the header seal **150** towards the hard plastic ring **130**. This lower internal pressure of the main seal **140** allows the higher pressure of the pumped fluid to flow between the inner and outer diameter surfaces **142**, the plunger **101**, and the housing flange **104**, hydraulically floating the main seal **140** during operation.

Sealing of the cylinder **108** occurs in a narrow area between the hard plastic ring **130** and the housing flange **104**, and the hard plastic ring **130** and the plunger **101**. During a pumping stroke of the plunger **101**, the material of the main seal **140** flows into the very narrow areas between the inner and outer diameter surfaces **132** of the hard plastic ring **130**, the plunger **101**, and the housing flange **104**. As the main seal **140** flows or extrudes into the narrow areas between the hard plastic ring **130**, the housing flange **104**, and the plunger **101**, the narrowness of the space increases the contact pressure between the main seal **140**, the housing flange **104**, and the plunger **101** to a pressure higher than the pumping pressure. In this manner, the packing assembly **106** seals the space between the plunger **101** and the housing flange **104**. During the suction stroke of the plunger **101** the pumping pressure drops and the main seal **140** flows out of the narrow gap between the hard plastic ring **130**, the housing flange **104**, and the plunger **101**.

Extrusion of or flow of the main seal **140** occurs along the length of the narrow gap between the hard plastic ring **130**, the housing flange **104**, and the plunger **101** exceeding the elongation properties of the main seal **140** and fatiguing the main seal **140**. At the corner where the main seal **140** meets the hard plastic ring **130** adjacent to the plunger **101**, i.e., the heel of the main seal **140**, the main seal **140** experiences extreme sheer loads during operation due to the motion of the plunger **101**. Consequently, the heel of the main seal **140** fatigues and fails first. Repeated extrusion and return of the main seal **140** into the narrow gap between the hard plastic ring **130**, the housing flange **104**, and the plunger **101** cause the extruded portions to begin to tear and flake off. Eventually, enough of the main seal **140** volume is lost and can no longer extrude into the narrow space between the hard plastic ring **130**, the housing flange **104**, and the plunger **101**. When this occurs, the high pressure of the pumped fluid causes catastrophic failure of the packing assembly **106**.

Referring now to FIG. **3**, an embodiment of the packing assembly **106** comprises a wedge-type back-up seal or hard plastic ring **200**. The wedge-type back-up seal **200** includes a rearward wedge ring **201** and a forward wedge ring **202**. In the illustrated embodiment, the rearward wedge ring **201** comprises an approximately triangular cross sectional area defined by a rearward annular vertical surface **203** abutting an end of the brass lantern ring **120** opposite the threaded retainer nut **107** (not shown in FIG. **3**), a cylindrical inner diameter surface **205** adjacent to the plunger **101**, and a forward angled surface **207** extending between an upper end of the vertical surface **203** and an end of the inner diameter surface **205** opposite the brass lantern ring **120**.

The cylindrical inner diameter surface **205** comprises a flat surface adjacent to the plunger **101**, a cylindrical wall surface **216**, and a flat end wall **214**. The cylindrical wall surface **216** can be transverse or perpendicular to the recess **110** and connects with the flat end wall **214** to form a rounded 90 degree corner. The flat end wall **214** can be transverse or parallel to the recess **110**. In other embodiments, the cylindrical wall surface **216** and flat end wall surface **214** connect to form a corner having an angle in the range of from greater than 30 degrees to less than 150 degrees, from about 30 degrees to about 120 degrees, or from about 60 degrees to about 100 degrees.

The rearward wedge ring **201** defines a portion of an annular inner extrusion recess **210** proximate to a main seal **140'** and extending vertically inward from the inner diameter surface **205** toward the housing flange **104**. The inner extrusion recess **210** is at the intersection of the inner diameter **205** and the angled surface **207**. The inner extrusion recess **210** extends a selected distance from the vertical surface **203**, terminating at the flat end wall **214**. The inner extrusion recess **210** is defined by the cylindrical wall **216** that is a short distance from the angled surface **207**. The annular inner extrusion recess **210** is further defined by a corner of the forward wedge ring **202** and an annular convex surface **141'** of the main seal **140'**. When the plunger **101** is in the forward position, the plunger **101** defines the bottom surface of the annular inner extrusion recess **210**. When the plunger **101** is in the rearward position, the annular inner extrusion recess **210** has no bottom surface and can be open to cylinder **108**.

The forward wedge ring **202** comprises a cross sectional area defined by a forward annular convex surface **204** abutting an adjacent end of the main seal **140'** opposite the header seal **150**, a cylindrical outer diameter surface **206** adjacent the housing flange **104**, and a rearward angled surface **208** extending between a lower end of convex surface **204** and an end of outer diameter surface **206** proximate to the brass lantern ring **120**. The angled surface **208** of the forward wedge ring **202** abuts and corresponds to the angled surface **207** of the rearward wedge ring **201**.

The angled surfaces **207**, **208** of the rearward and forward wedge rings **201**, **202** are determined so that the inner and outer surfaces **205**, **206** of the wedge rings exerts pressure against the plunger **101** and housing flange **104** in an amount that is slightly higher than the contact pressure between the main seal **140'** and plunger **101** and the main seal **140'** and the housing flange **104**.

An embodiment provides that the angled surfaces **207**, **208** can be complementary angles to each other, for example, the angle of **207** and the angle of **208** together equal about 90 degrees. The angled of the surfaces **207**, **208** of the rearward and forward wedge rings **201**, **202** can be from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the recess **110** and having a corner at the recess **110** or an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101**. In alternate embodiments, the angle of the surfaces **207**, **208** of the rearward and forward wedge rings **201**, **202** can be from about 25 degrees to about 70 degrees relative to an axis perpendicular to the longitudinal axis of the recess **110** and having a corner at the recess **110** or an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101**.

Referring to FIG. **3**, the angled surface **207** of the rearward wedge ring **201** is oriented at about 45 degrees relative to the vertical surface **203** or an axis perpendicular to the longitudinal axis of the recess **110** having a corner at recess **110**. The angled surface **208** of the forward wedge ring **202** is at an angle complementary to the angle surface **207**. For example and not limitation, the angled surface **208** of the forward wedge ring has an angle A of 45 degrees relative to an axis perpendicular to the longitudinal axis of the recess **110** having a corner at recess **110**.

The forward wedge ring **202** defines a portion of an annular outer extrusion recess **211** proximate to the main seal **140'** and extending vertically inward from the outer diameter surface **206** toward the plunger **101**. The outer extrusion recess **211** is at the intersection of the outer diameter surface **206** and the convex surface **204**. The outer extrusion recess **211** extends a selected distance from the convex surface **204**, terminating in a flat end wall **215** of the forward wedge ring **202**. The flat end wall **215** is transverse or parallel to the cylinder **110**. The outer extrusion recess **211** is further defined by a cylindrical wall **217** that is a short distance from the convex surface **204**. The cylindrical wall **217** is transverse or perpendicular to the cylinder **110**. Preferably, the corner where the flat end wall **215** intersects with the cylindrical wall **217** is rounded and at an angle of about 90 degrees. However, in other embodiments the flat end wall **215** and the cylindrical wall **217** connect to form a corner having an angle in the range of from greater than 30 degrees to less than 150 degrees, from about 30 degrees to about 120 degrees, or from about 60 degrees to about 100 degrees. The cylinder **110** defines the upper surface of the outer extrusion recess **211**. An annular concave surface **141'** of the main seal **140'** defines the forward surface of the outer extrusion recess **211**. A person skilled in the art will understand that embodiments may include only the inner extrusion recess **210** or the outer extrusion recess **211** as well as both the inner and the outer extrusion recesses **210**, **211** as illustrated herein.

In the embodiment illustrated in FIG. **3**, a cross section of the main seal **140'** is defined by the annular concave surface **141'** abutting the convex surface **204** of the forward wedge ring **202**. The cross section also comprises inner and outer diameter surfaces **142'**, and an annular concave surface **143'** opposite the vertical surface **141'**. The remainder of seal assembly **106** includes the portions of seal assembly **106** illustrated and described with respect to FIG. **2** including the header seal **150** and junk ring **160**.

In operation, as illustrated at FIG. **4**, the threaded retainer ring **107** (not shown) is tightened exerting an axial force against the brass lantern ring **120**. The force exerted by the threaded retainer ring **107** (not shown) causes a reacting force in the shoulder **111** (not shown). These opposing forces transfer through the packing assembly **106** and cause the soft header seal **150** to deform as shown in FIG. **4**. The deformation of the header seal **150** exerts a setting force on the main seal **140'** pressing the opposing inner and outer diameter surfaces **142'** into contact with the interior wall of the housing flange **104** and the exterior surface of the plunger **101**. When the plunger **101** strokes horizontally in FIG. **4**, high pressure on the main seal **140'** forces the rearward wedge seal **201** into tight contact with the plunger **101**. Similarly, the high pressure forces on the main seal **140'** cause the angled surface **208** of the forward wedge seal **202** to slide upward along the angled surface **207** of the rearward wedge seal **201** coming into tight contact with the housing flange **104**. Thus, unlike the hard plastic ring **130** of FIG. **2**, the narrow gaps between the wedge-type hard plastic ring **200**, the plunger **101**, and the housing flange **104** are closed.

In the preferred embodiment, a portion of the main seal **140'** then extrudes into the inner extrusion recess **210** and the outer extrusion recess **211**. The geometry of the inner extrusion recess **210** and the outer extrusion recess **211** is selected such that portions of the main seal **140'** will flow or extrude into the extrusion recesses **210**, **211** to create a contact pressure between the main seal **140'**, the plunger **101**, and the housing flange **104** that is higher than the pump fluid pressure without the extrusion exceeding the elongation properties of the main seal **140'**. A person skilled in the art will understand that alternative embodiments may include only one extrusion recess.

The suction stroke of the plunger **101** relieves the high pressure in the cavity **103** (not shown) and the extruded portions of the main seal **140'** return to their original shape. Thus, the extrusion recesses **210**, **211** provide areas for controlled extrusion of the main seal **140'** that limit the thinness of the extrusion during operation. Allowing a preset volume of extrusion into the extrusion recesses **210**, **211** decreases the intensity of the stresses on the extruded portions of the main seal **140'** over the main seal **140** as described with respect to FIG. **2**. Furthermore, the rounded corners defining the extrusion recesses **210**, **211** eliminate additional localized stresses in the main seal **140'** caused by the corners of the hard plastic seal **130** on the main seal **140** of FIG. **2**. The reduction in stress on the main seal **140'** extends the life of the main seal **140'** of FIG. **3** and FIG. **4** while still allowing for a tight seal of the cylinder **108** between the housing flange **104** and the plunger **101**.

FIG. **5** illustrates an embodiment of a packing assembly **106** comprising a wedge-type back up seal or hard plastic ring **200'**. The wedge-type back-up seal **200'** includes a rearward wedge ring **201'** and a forward wedge ring **202'**. In the illustrated but non-limiting embodiment, the rearward wedge ring **201'** comprises an approximately triangular cross sectional area similar to the embodiment shown in FIG. **3**. However, unlike FIG. **3**, the angled surface **207'** of the rearward wedge **201'** is at an angle originating from an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101**.

The forward wedge ring **202'** comprises a triangular cross sectional area and includes an angled surface **208'** having an angle originating from an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101**. The forward wedge ring **202'** includes an extrusion recess at the top of the triangle for controlled expansion of the main seal **180**. The extrusion recess is provided at the intersection and on the forward sides of the rearward and forward wedge rings **201'**, **202'**.

The angled of the surfaces **207'**, **208'** of the rearward and forward wedge rings **201'**, **202'** can be from about 20 degrees to about 85 degrees relative an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101** or 25 degrees to about 70 degrees relative to an axis perpendicular to the longitudinal axis of the plunger **101** and having a corner at the plunger **101**.

The angled surfaces **207'**, **208'** and the extrusion recess formed on the forward sides of the rearward and forward wedge rings **201'**, **202'** are selected such that portions of the main seal flow or extrudes in the extrusion recess to create contact pressure between the main seal **180**, the plunger **101**, and the housing flange **104** that is the higher than the pump fluid pressure without the extrusion exceeding the elongation properties of the main seal **180**. The reduction in stress on the main seal **180** extends the life of the main seal **180** of FIG. **5** and while providing a tight seal of the cylinder **108** between the housing flange **104** and the plunger **101**.

In the foregoing description of certain embodiments, specific terminology has been resorted to for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes other technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as "left" and right", "forward" and "rearward", "above" and "below" and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

In this specification, the word "comprising" is to be understood in its "open" sense, that is, in the sense of "including", and thus not limited to its "closed" sense, that is the sense of "consisting only of". A corresponding meaning is to be attributed to the corresponding words "comprise", "comprised" and "comprises" where they appear.

In addition, the foregoing describes only some embodiments alterations, modifications, additions and/or changes can be made thereto without departing from the scope and spirit of the disclosed embodiments, the embodiments being illustrative and not restrictive.

Furthermore, embodiments have described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the embodiments are not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the embodiment(s). Also, the various embodiments described above may be implemented in conjunction with other embodiments, e.g., aspects of one embodiment may be combined with aspects of another embodiment to realize yet other embodiments. Further, each independent feature or component of any given assembly may constitute an additional embodiment.

The invention claimed is:

1. A seal assembly for use within an annular recess of a cylindrical chamber for receiving a plunger in a pump, the seal assembly comprising:

a main seal having an axis, a forward side, and a rearward side;

a back-up seal configured to be in abutment with the rearward side of the main seal, the back-up seal having inner and outer diameter cylindrical surfaces;

the back-up seal being of a material harder than a material of the main seal and being expansible in a radial direction that is perpendicular to the axis of the main seal in response to an axially directed force;

at least one extrusion recess on a forward side of the back-up seal for receiving an extruded portion of the rearward side of the main seal during a forward stroke of a pump plunger; and

wherein the backup seal comprises a rearward wedge ring and a forward wedge ring each of the wedge rings having a cylindrical surface, wherein the rearward wedge ring and the forward wedge ring each have a mating angled surface configured to slide against one another such that the rearward and forward wedge rings can slidingly move in the radial direction to adjust a combined radial width relative to a cylinder chamber during operation of a pump and to receive the extruded portion of the main seal at least partially within the extrusion recess during a forward stroke of a pump plunger.

2. The seal assembly of claim **1**, wherein the rearward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

3. The seal assembly of claim **1**, wherein the forward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

4. The seal assembly of claim **1**, wherein the rearward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of a plunger, if the rearward wedge ring is disposed within an annular recess of a cylindrical chamber for receiving a plunger.

5. The seal assembly of claim **1**, wherein the forward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of a plunger, if the rearward wedge ring is disposed within an annular recess of a cylindrical chamber for receiving a plunger.

6. The seal assembly of claim **1**, wherein the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

7. The seal assembly of claim **1**, wherein the extrusion recess extends a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings, defining a forward facing step at a rearward end of the extrusion recess.

8. The seal assembly of claim **1**, wherein the extrusion recess has an entrance substantially at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

9. The seal assembly of claim **1**, wherein:

the forward wedge ring has a forward facing convex surface adjacent to and in contact with a rearward facing concave surface of the main seal; and

the extrusion recess is positioned at a rearward end of the convex surface portion.

10. The seal assembly of claim **1**, wherein the at least one extrusion recess comprises two extrusion recesses, each located at a forward edge of one of the cylindrical surfaces.

11. The seal assembly of claim **1**, wherein the extrusion recess has an entrance at an intersection of the mating angled surface with the cylindrical surface of at least one of the wedge rings.

12. A reciprocating pump assembly comprising:

a pump housing defining a pump cavity in an interior of the housing and a cylinder chamber extending from an exterior of the pump housing to the pump cavity;

a plunger disposed at least partially within the cylinder chamber and configured to reciprocate in an axial direction into and out of the pump cavity in rearward and forward directions between suction and discharge strokes, respectively;

an annular recess formed in the cylinder chamber and positioned between an exterior of the pump housing and the pump cavity;

a seal assembly having a main seal in abutment with a wedge-type seal disposed within the recess, the seal assembly configured to seal the plunger to the cylinder chamber;

wherein the wedge-type seal comprises a rearward wedge ring and a forward wedge ring each of the wedge rings having a cylindrical surface;

wherein the rearward wedge ring and the forward wedge ring have mating angled surfaces configured to slide against one another such that in response to the sliding movement, the rearward and forward wedge rings move in a radial direction perpendicular to the axial direction to increase their combined radial width relative to an axis of the cylinder chamber during a discharge stroke;

at least one extrusion recess formed on at least one of the wedge rings; and

wherein during the discharge stroke of the plunger a rearward portion of the main seal extrudes into the extrusion recess.

13. The pump assembly of claim **12**, wherein the at least one extrusion recess is on a forward edge of the cylindrical surface.

14. The pump assembly of claim **12**, wherein the rearward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

15. The pump assembly of claim **12**, wherein the forward wedge ring has an angled surface in the range of from 20 degrees to 85 degrees relative to an axis perpendicular to the longitudinal axis of the annular recess.

16. The pump assembly of claim **12**, wherein the rearward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

17. The pump assembly of claim **12**, wherein the forward wedge ring has an angled surface in the range of from about 20 degrees to about 85 degrees relative to an axis perpendicular to the longitudinal axis of the plunger.

18. The pump assembly of claim **12**, wherein the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

19. The pump assembly of claim **13**, wherein the extrusion recess extends a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings, defining a forward facing step at a rearward end of the extrusion recess.

20. The pump assembly of claim **12**, wherein during the discharge stroke, one of the cylindrical surfaces is in contact with the plunger and the other is in contact with the annular recess in the cylindrical chamber.

21. The pump assembly of claim **12**, wherein the extrusion recess has an entrance at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

22. The pump assembly of claim **12**, wherein:

an inner one of the cylindrical surfaces is in sliding engagement with the plunger; and the extrusion recess is located on the cylindrical surface of the inner one of the cylindrical surfaces.

23. The pump assembly of claim **12**, wherein the at least one extrusion recess comprises two extrusion recesses, each located at a forward edge of one of the cylindrical surfaces.

24. The pump assembly of claim **12**, wherein:

the forward wedge ring has a forward facing convex surface adjacent to and in contact with a rearward facing concave surface of the main seal; and

the extrusion recess is positioned at a rearward end of the convex surface portion.

25. The pump assembly of claim **12**, wherein the extrusion recess has an entrance at an intersection of the angled surface with the cylindrical surface of at least one of the wedge rings.

26. The pump assembly of claim **12**, wherein the main seal is formed of a material that is softer than the material of the wedge ring.

27. A method for sealing a plunger to a pump housing within a reciprocating pump assembly, the method comprising:

(a) providing a seal assembly having a main seal and a back-up seal, the back-up seal being of a material harder than a material of the main seal and being expansible in a radial direction for increasing a width between inner and outer diameter cylindrical surfaces in response to an axially directed rearward force, and at least one extrusion recess for receiving an extruded portion of the rearward side of the main seal during a forward stroke of the pump plunger;

(b) positioning the seal assembly within a recess of a cylinder chamber that extends between an exterior of the pump housing and a pump cavity;

(c) inserting a plunger into the cylinder chamber so that an exterior diameter of the plunger contacts the seal assembly;

(d) reciprocating the plunger into and out of the pump cavity through the cylinder chamber; and

(e) as the plunger moves forward relative to the seal assembly, expanding a radial width of the back-up seal and extruding a portion of the main seal into the extrusion recess of the back-up seal, wherein expanding a radial width of the back-up seal includes providing a forward wedge ring and a rearward wedge ring each having a mating angled surface sliding against one another such that the rearward and forward wedge rings slidingly move in the radial direction to expand the radial width of the back-up seal.

28. The method of claim **27**, wherein step (a) further comprises the extrusion recess is on a forward side of the back-up seal at an intersection of the forward side with one of the cylindrical surfaces and extending the extrusion recess a selected distance rearward from the forward edge of the cylindrical surface of at least one of the wedge rings to define a forward facing step at a rearward end of the extrusion recess.

29. The method of claim **27**, wherein step (e) comprises contacting the plunger with one of the cylindrical surfaces of the back-up seal and contacting the annular recess in the cylindrical chamber with the other cylindrical surface of the back-up seal.

30. The method of claim **27**, wherein an inner one of the cylindrical surfaces is in sliding engagement with the plunger, and step (a) further comprises locating the extrusion recess on the cylindrical surface of the inner one of the cylindrical surfaces.

31. The method of claim **27**, wherein the at least one extrusion recess comprises two extrusion recesses and step (a) comprises locating each extrusion recess at a forward edge of one of the cylindrical surfaces.

32. The method of claim **27**, wherein the at least one extrusion recess is at an intersection of the rearward and forward wedge rings.

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